Institution: University of Southampton

Unit of Assessment: 15 General Engineering

Title of case study: 15-02 Dezineforce - pioneering cloud computing

1. Summary of the impact

Cloud computing is now used ubiquitously in consumer and commerce domains yielding unprecedented access to computing and data handling at affordable prices.

Work in this field was pioneered at the University of Southampton (UoS) from 1998 onwards and commercialised from 2008 through Dezineforce to enable companies to exploit **cloud computing in engineering**:

- The technology was applied in industries including aerospace and defence, energy, civil engineering and automotive.
- For **small companies**, we successfully demonstrated access to computing power and enhanced design tools delivered via the Cloud. e.g. Intelligent Flow Solutions used our tools to develop an innovative Wind Turbine Farm design with an increased lifetime return of over €55 million compared to alternative arrangements.
- **Large companies** benefited from more efficient ways of collaborative working and advanced design search/ optimisation technologies, which had not been possible before. For example Arup achieved a £1 million+ figure saving on a stadium design in the Middle East.
- The IP was sold to Microsoft in 2011 with staff moving to roles in Microsoft's Azure Cloud/ senior teams.

Throughout this period the team has also engaged in **outreach** to inspire and educate the next generation of scientists and engineers about High Performance and Cloud computing including a YouTube video with 485,000 hits and over 300 articles in media.

2. Underpinning research

The underpinning research was performed in the EPSRC funded "PSE" and "Geodise" eScience **[3.1]** projects (1998-2005), the Microsoft Institute for High Performance Computing (Microsoft-funded 2005 onwards and launched by Bill Gates), and also led to the £17.8 million Centre for Fluid Mechanics Simulation Department of Trade and Industry (DTI) research and development project (2007-2010) which involved aerospace, automotive and supply chain partners where Cox led the IT Work package for Microsoft.

Geodise posed the question "*How can companies get access to and exploit high performance distributed computing and data handling resources, industrial strength analysis and design search tools over the web and affordably*?" and focussed on showing how these technologies could be used to make engineering artefacts and whole systems *faster, cheaper, greener, and/ or better*.

Today we recognise these aims as those of **cloud computing** and they address the strategic commercial need to lower entry costs and (for engineering) the competitive imperative of improving the productivity of computer-assisted design.

Geodise was a multi-disciplinary, multi-site collaboration with industrial partners including Rolls-Royce, BAE Systems, Fluent and Microsoft. The project involved expertise at Southampton on engineering, design search, semantic technologies and distributed computing & data; Oxford on fluid dynamics solvers and Manchester on knowledge systems.

The Geodise tools **[3.1]** enabled distributed teams of engineers to access large scale computing and data handling on the cloud **[3.2]** to tackle complex tasks such as those in aerospace design **[3.3]** using state of the art design search tools **[3.4]**, industry strength and novel solvers **[3.5]**.

We continued this fundamental work from 2005 onwards through the Microsoft Institute for High Performance Computing (HPC) at Southampton, which was the only such centre Microsoft funded in the UK (and one of only ten worldwide). This specifically recognised our pioneering of HPC and cloud computing, where we worked closely with Microsoft over subsequent years on their Windows

HPC Server product & Cloud offering (Azure): we were part of their showcase stand from 2005-2011 at the US "Supercomputing" conference series (the largest of its kind in this field). In 2007, Cox was awarded a technical leadership prize by Microsoft CEO Steve Ballmer for his contribution to Technical Computing, which highlighted the breadth and depth of his ongoing relationship with Microsoft.

The research carried out under the Geodise project was commercialised by the company Dezineforce which was founded by Prof Simon Cox (UoS from 1994), Prof Andy Keane (UoS from 1996) and Prof Sir Nigel Shadbolt (UoS from 2000).

Cox led the funding of the company from 2005-2008, and hired a Chairman and CEO with assistance from Prof John Baits (a visiting professor at the University, ex IBM). Five members of the team joined the spin-out from the University. Grants and collaboration with the Company occurred between 2007 and 2011 - along with joint research activity, the University provided commercial hosting for Dezineforce's equipment. The company's IP was sold to Microsoft in May 2011 with the transfer of IP and 6 members of staff.

The research has also led to media outreach (over 300 articles in worldwide news, magazines, and YouTube) and a course "Supercomputing in Engineering" in conjunction with the Smallpeice trust with over 200 attendees over the last seven years with a course rating of over 90%.

3. References to the research (best 3 outputs are starred)

*[3.1] Main Geodise Reference: Eres, M.H., Pound, G.E., Jiao, Z., Wason, J.L., Xu, F., Keane, A.J., and Cox, S.J. Implementation and utilisation of a Grid-enabled problem solving environment in Matlab. Future Generation Computer Systems, Vol. 21, No. 6, 2005, pp. 920-929.

EPSRC GR/M17259/01: "PSE" (Problem solving environments for Large-Scale Simulations) 1998-2001. EPSRC: GR/R67705/01: "Geodise" (Grid Enabled Optimisation & Design Search for Engineering) 2001-2005

[3.2] Fundamental: Xue G., Song W., Cox S.J., and Keane A.J., Numerical Optimisation as Grid Services for Engineering Design. Journal of Grid Computing, Vol.2, No.3, 2004, pp. 223-238.

[3.3] Book: Keane, A.J. and Prasanth, P.B. Computational Approaches for Aerospace Design: The Pursuit of Excellence. John Wiley & Sons, Chichester, UK. 2005.

*[3.4] Book: Forrester, A., Sóbester, A., and Keane, A.J., .Engineering Design via Surrogate Modelling: A Practical Guide. Chichester, West Sussex, England: John Wiley & Sons Ltd., 2008.

*[3.5] New Adjoint solver: Campobasso M.S., Duta M.C. and Giles M.B., Adjoint Calculation of Sensitivities of Turbomachinery Objective functions. AIAA Journal of Propulsion and Power, Vol. 19, No. 4, July-August 2003, pp. 693-703.

[3.6] Ongoing research and outreach: Cox S.J., Cox J.T., Boardman R.P., Johnston S.J., Scott M., O'Brien N.S., "Iridis-pi: a low-cost, compact demonstration cluster" Cluster Computing June 2013 DOI: 10.1007/s10586-013-0282-7. YouTube video for this at http://www.youtube.com/watch?v=Jq5nrHz9I94 has 485,000 views [as at Oct 2013]

4. Details of the impact

Sophisticated computer simulations are used in many sectors of industry to reduce the high cost of prototyping and experiment and to provide better answers to complex problems in less time.

Research conducted as part of the Geodise project led to the development of tools and technologies which were accessible over the web "on-demand" (*cloud computing*) to make engineering designs faster, cheaper, greener, better. We commercialised this work through Dezineforce, whose products and services were tested and used by design engineers to optimise designs in a range of industries including aerospace and defence, energy, civil engineering and automotive.

In Civil Engineering **Arup** used the dezineforce tools in 2008/9 to design a spectator cooling system in a 65 000-seater sports stadium in the Middle East. Using Dezineforce's service, Arup reduced the number of design iterations by over 80 percent and saved valuable time and a £1million+ figure sum for the stadium owners. Darren Woolf, Associate Director of Arup's

Environmental Physics team who led the analysis explained the benefits **[5.1]**:

"Because CFD is so computationally hungry, each one of our design iterations could take up to eight hours to run on eight computers working in parallel. It would have needed, using traditional direct search techniques, as many as 300 design iterations per scenario. A key objective for us was to reduce this number of design iterations needed to reach a solution. Dezineforce's optimisation technology enabled us to evolve an optimum design faster than other algorithms out there and we saw the number of runs required drop by more than 80 percent from what we were predicting." … *"There is no question that engineering design optimisation is complex and processor hungry but, implemented correctly with well-designed processes, such as those from Dezineforce, coupled with high performance processing resources, it can be a very powerful tool."*

Other work included optimisation of wind farm layout with UK company **Intelligent Fluid Solutions** in 2009 **[5.2]**, where efficient use of optimisation-driven simulation enabled the optimum number and layout of wind turbines for a specific site to be identified. This resulted in a predicted increased lifetime return of over €55 million compared to the same number of turbines in an alternative arrangement. Dr Andrej Horvat, Principal Engineer, Intelligent Flow Solutions presented his conclusions of joint study using Dezineforce cloud and optimisation technologies:

"*A CFD based modelling methodology was developed to predict wind farm power output for a given investment. Different wind farm layouts were simulated to calculate power output of the wind farm; The analysis shows that the same number of turbines in different layouts can result in significantly different yield. With alternate offset rows, wide, shallow wind farms are most profitable; the use of computational simulation methods and advanced optimisation tools can result in significant performance improvements.*"

Dezineforce also worked closely to have an impact with leading suppliers of modelling tools in the industry to bring new ways to access licenses and HPC tools to customers. Previously companies sold only expensive licenses whereas working with Dezineforce, software companies such as ANSYS, CD-Adapco, and MSc-Nastran realised that many clients want to rent their software by the hour or for a specific project. In particular, partnership with Dezineforce companies such as Ansys developed new pricing structures & models for license usage amenable to HPC and engineering design search tasks. Dezineforce was one of the first companies to offer these packages in this flexible way over the cloud or on site. Barbara Hutchings, Director of Strategic Partnerships at **ANSYS Limited** and Lionel Humpheys (sales manager) commented in April 2010 on these changes to licensing with Dezineforce during at a webcast (quote from Q&A): **[5.3]**

"The [Dezineforce] HPC Appliance is designed to work with ANSYS Mechanical, ANSYS CFX, and ANSYS Fluent. If you happen to own parallel licenses of these products, all of these could be traded back at 100% of their original list prices, and we will trade them back for HPC licenses. In certain instances, it may mean you get an increase of license count — an increase in the number of parallel sessions you can run at no additional cost."

Microsoft has engaged heavily with the University of Southampton and Dezineforce. Vince Mendillo **[5.4]**, Senior Director of High Performance Computing at Microsoft (in Nov 2009) commented:

"Windows HPC server is enabling scientists and engineers around the world to tackle challenging research problems. We are very excited about the tremendous work the team at the University of Southampton has been doing to bringing supercomputing to the masses."

At Supercomputing in Nov 2010, Dezineforce and the University of Southampton, using Microsoft Windows HPC Server R2, Microsoft Azure, and the Dezineforce technical computing server, showed how an engineer can seamlessly scale their complex design analysis from their client workstation, to a local cluster, and then onto an Azure cloud based platform **[5.5]**. This was the first demonstration of such a capability on Microsoft's technology using in-house HPC systems, cloud computing and running licensed 3rd party software coupled to optimisation tools. Microsoft worked closely with the team in Dezineforce and it was one of the first UK companies recognised as part of its BizSpark One programme (2010) **[5.6]** and Dezineforce's IP was sold to Microsoft in 2011 with transfer of 6 staff to key roles in its Azure (Cloud)/ senior team.

For more than a decade, the partnership between the University of Southampton and Microsoft has continued to impact on Microsoft's global business proposition and has received funding of over £1 million from Microsoft in the last 5 years alone. Cox has been awarded Microsoft Most Valuable Professional (MVP) status every year since 2003 **[5.7]**. In 2010 Cox was appointed, along with Southampton's Dr Kenji Takeda, as a founder member of Microsoft's Technical Computing Executive Advisory Council, which includes CIOs of Fortune 20 companies. Takeda has since joined Microsoft as Solutions Architect and Technical Manager in its research team (from 2010).

Outreach. The University of Southampton continues to inspire the next generation of scientists and engineers – especially relating to the use of high performance/ cloud computing. Cox's "Supercomputing in Engineering" course **[5.8]** with the **Smallpeice Trust** has run annually with 25+ sixth form students since 2006 with a content rating of 90%+ from participants with comments such as "*Day two on the course kicked off with Simon's talk on algorithms and efficiency in supercomputer. I loved this talk because it summed up everything I was interested in computers*".

Lucy Kelly (Smallpeice Trust) commented in 2013 "*This course has demonstrated to some very intelligent and enthusiastic young people just how important this subject is and what a great impact they could have if they decided to pursue a career in this area*."

Over 485,000 [Oct 2013] people have viewed Cox's YouTube video **[5.9]** showing how the Raspberry Pi will enable the next wave of cheap commodity cloud/ supercomputing with news articles, video material and a full construction guide about the World's first **Raspberry Pi + Lego Supercomputer**: 300+ worldwide news/ tech press items in multiple languages including BBC, CNET, PC Pro Magazine (where it was the #1 Raspberry Pi project in their Christmas 2012 edition), and 10,000+ Tweets & Facebook likes of the news coverage.

Liz Upton **[5.10]** [liz@raspberrypi.org]; the only paid employee of the **Raspberry Pi Foundation** at the time of writing her mail, who handles all of their external public-facing interactions wrote to Cox on 12/09/12 about the story above:

> *"Thank *you* - we were tickled to bits when we saw it. Do give me a shout next time you do something Pi-related; I'm always looking for stuff for the blog, and I have suspicion you're not done yet!"*

Such outreach is contributing towards ensuring there is a pool of highly skilled workers who will pioneer the next wave of research and development into computational technologies for engineering just as we have done through Dezineforce and its underpinning research.

Cloud computing as exemplified by its penetration into consumer products such as music, photos, personal archiving and business products for office document and data sharing has fundamentally changed the way we use computing power and it touches many lives. Its application to Engineering problems was pioneered at the University of Southampton.

5. Sources to corroborate the impact

[5.1] Arup, Dr Darren Woolf

[5.2] Intelligent Flow Solutions, Dr Ondrej Horvat

[5.3] ANSYS Limited, Dr Barbara Hutchins, Director of Strategic Partnerships and Lionel Humpheys (sales manager)

[5.4] Microsoft Vince Mendillo, Senior Director of High Performance Computing at Microsoft

[5.5] Supercomputing 2010 public domain reference sources

[5.6] BizSpark One Dezineforce [Press and Video]

[5.7] Microsoft Most Valuable Professional (Cox)

[5.8] Supercomputing in Engineering Smallpeice Course

[5.9] Raspberry Pi Outreach [Press/ YouTube]

[5.10] Liz Upton, Raspberry Pi Foundation, email